

# **Advanced Liquid-Desiccant Technology**

**Dr. Andrew Lowenstein  
Principal Investigator  
AIL Research**

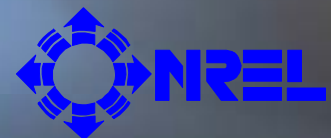
**IES Peer Review  
Nashville, TN  
April 30, 2002**

# Overview

- ◆ Develop a new generation of liquid-desiccant conditioners and regenerators based on low-flow technology
- ◆ Apply the new liquid-desiccant technology in thermally activated coolers/dehumidifiers that can maintain healthy and comfortable indoor conditions while reducing energy use
- ◆ Commercialize the technology first in industrial markets and expand to commercial/residential



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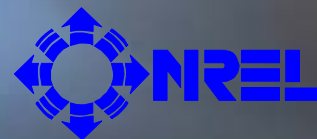


# Project Team and Partnerships

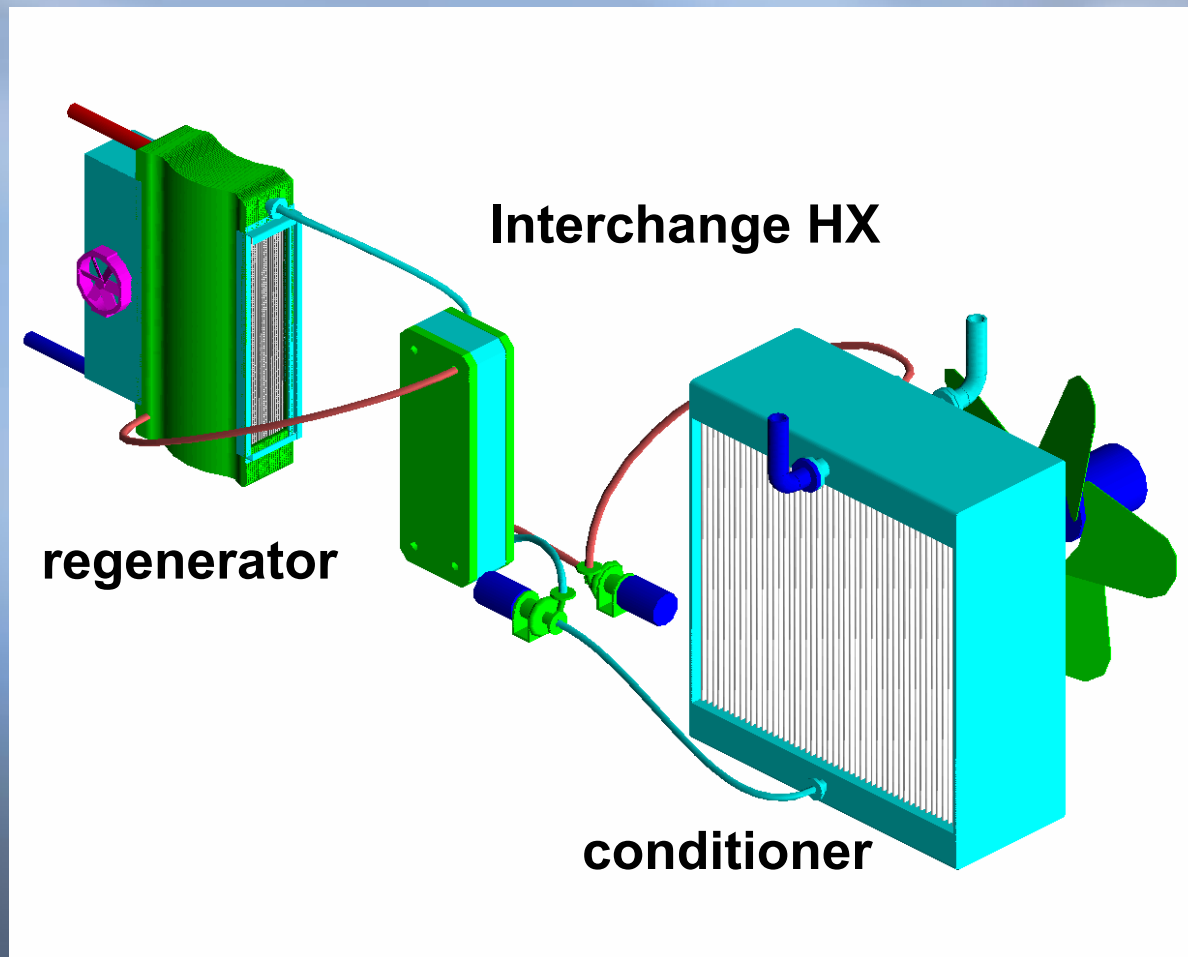
- ◆ **AIL Research, Inc.**
  - ◆ Founded in 1988
  - ◆ Eight engineers and machinists
  - ◆ Tool and die making
  - ◆ Advanced CAD/CAM capability
  - ◆ 2,000 s.f. lab and shop
- ◆ **Dr. Andrew Lowenstein, Principal Investigator**
- ◆ **Mr. Marc Sibilia, Vice President, Engineering**
- ◆ **Kathabar, Inc**
  - ◆ Industrial & institutional uses of new technology



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# Generic Liquid-Desiccant AC

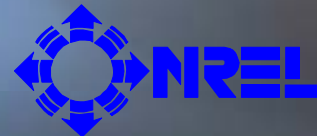


# Why Pursue Liquid Desiccants?

- ◆ *Heat and mass transfer in a single component*
  - ◆ low pressure drops
  - ◆ low surface area
  - ◆ high “specific” cooling
  - ◆ Relatively small size
- ◆ *Can use interchange HX*
  - ◆ improves efficiency
  - ◆ reduces heat “dump back”
- ◆ *High efficiency options for regeneration*
  - ◆ VCD regenerator can have COP over 2.0
- ◆ *Low temperature regeneration also possible*
  - ◆ 0.6 COP at 160 F
- ◆ *Potentially low first cost and operating costs*



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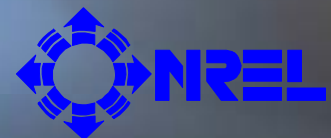


# Challenges of Using Liquid Desiccants

- ◆ Eliminate corrosion from liquid desiccant
- ◆ Reduce maintenance requirements
- ◆ Reduce size and lower equipment cost
- ◆ Develop high-efficiency regenerator



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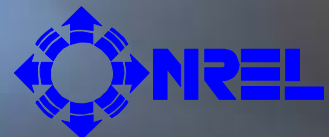


# Low-Flow Liquid-Desiccant Technology

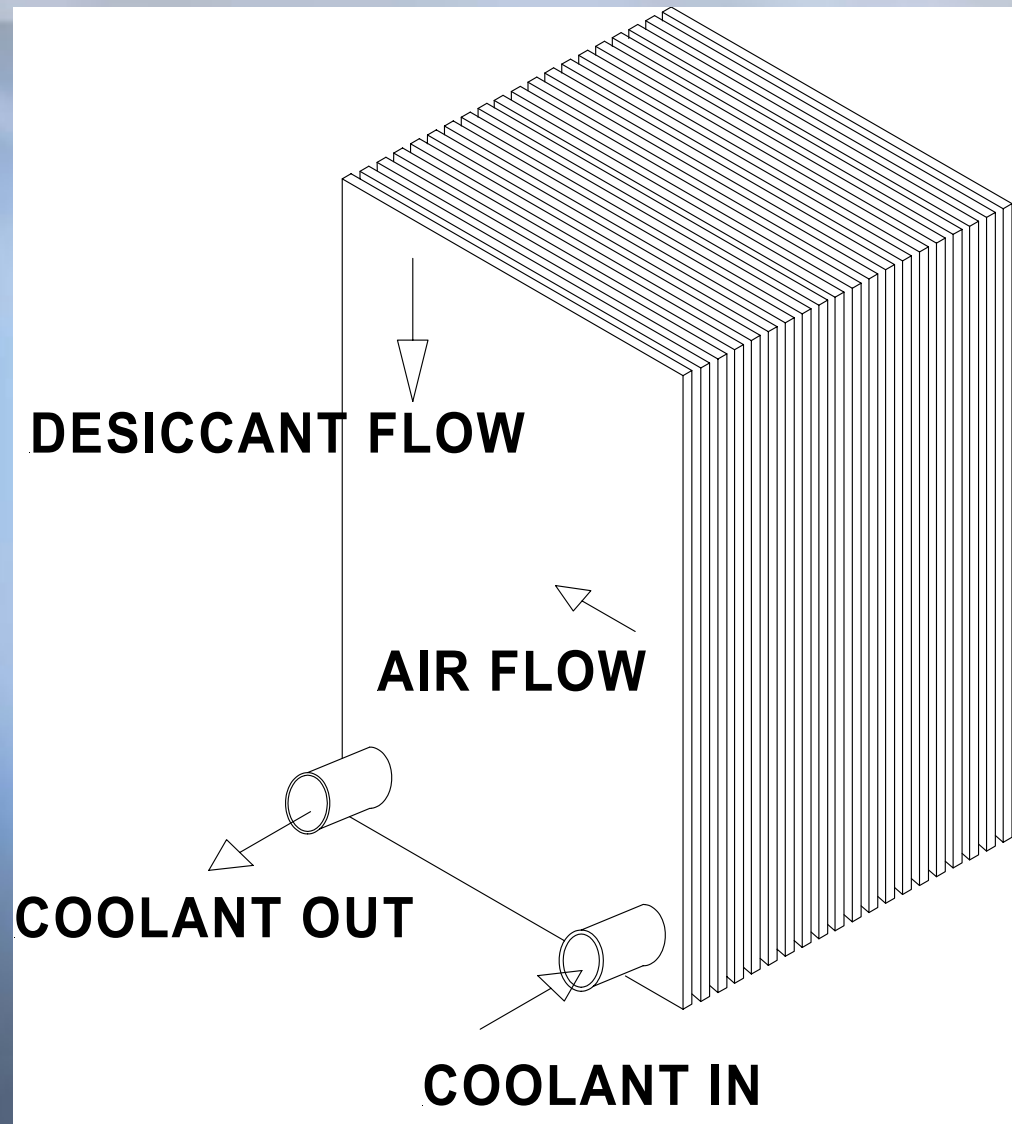
- ◆ Reduce desiccant flooding rates by factor of 10 to 50
- ◆ Must continually cool desiccant
- ◆ Potential to eliminate carryover of desiccant droplets
- ◆ Benefits include
  - ◆ Higher efficiency
  - ◆ Higher rate of air cooling
  - ◆ Lower pressure drops
  - ◆ Smaller equipment size
  - ◆ Lower first cost



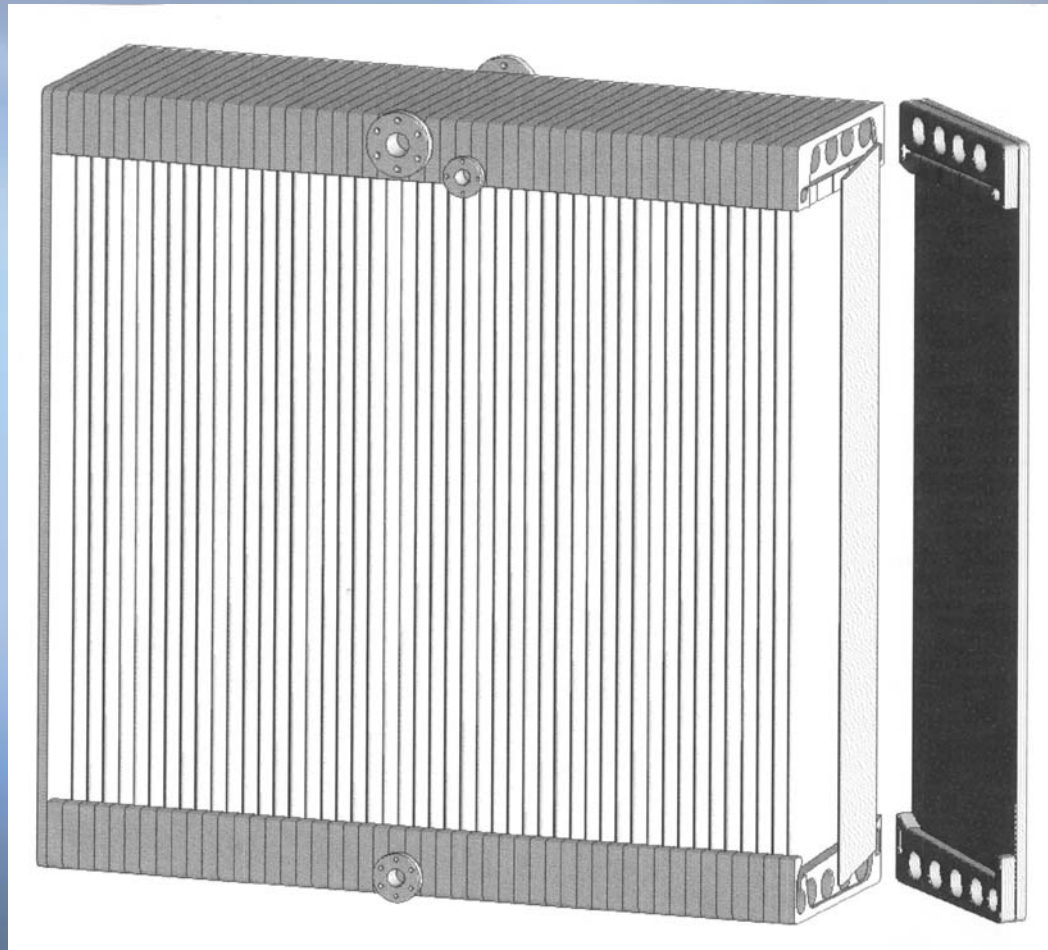
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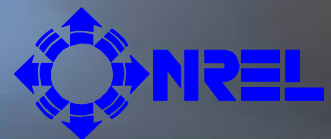
# Water-Cooled Zero-Carryover Conditioner



# Water-Cooled Zero-Carryover Conditioner



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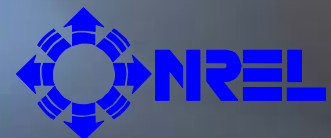


# Zero-Carryover Conditioner Project Accomplishments

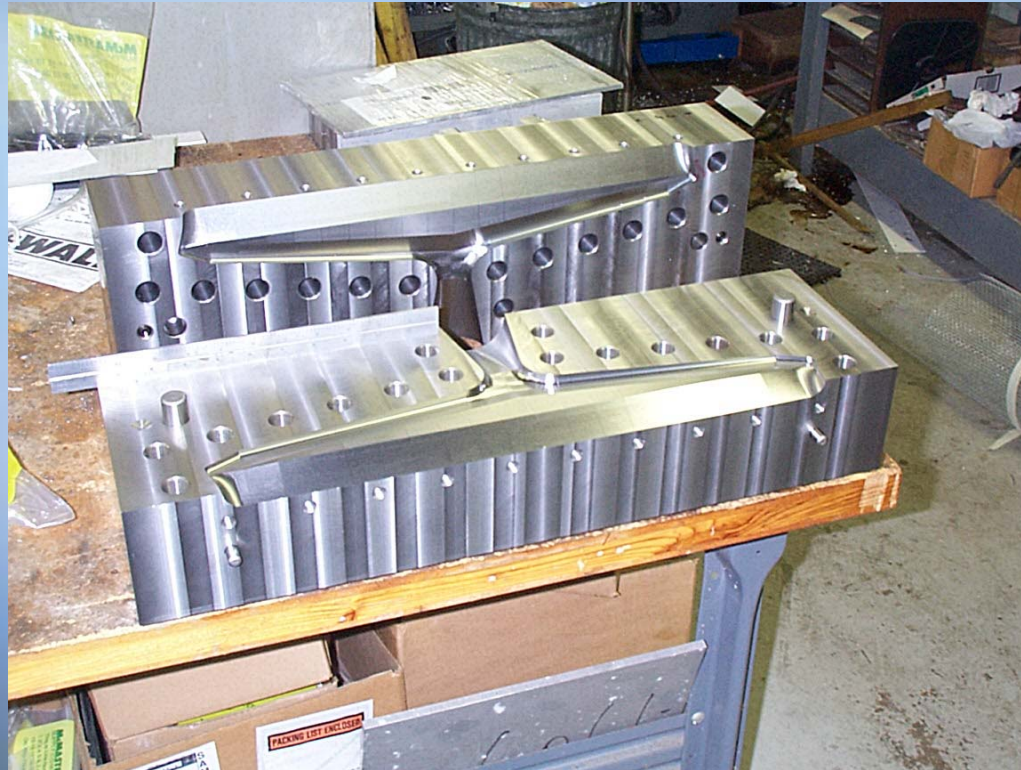
- ◆ Conditioner developed and performance proven
- ◆ Die and molds made for extrusion and injection-molded parts
- ◆ Robotic assembly station set up
- ◆ 40-plate model sent to NREL for evaluation
- ◆ 200-plate prototype completed; field test this summer at Kathabar
- ◆ Conceptual design completed for 1000-unit/year manufacturing line
- ◆ Manufacturing costs have been estimated



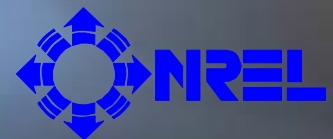
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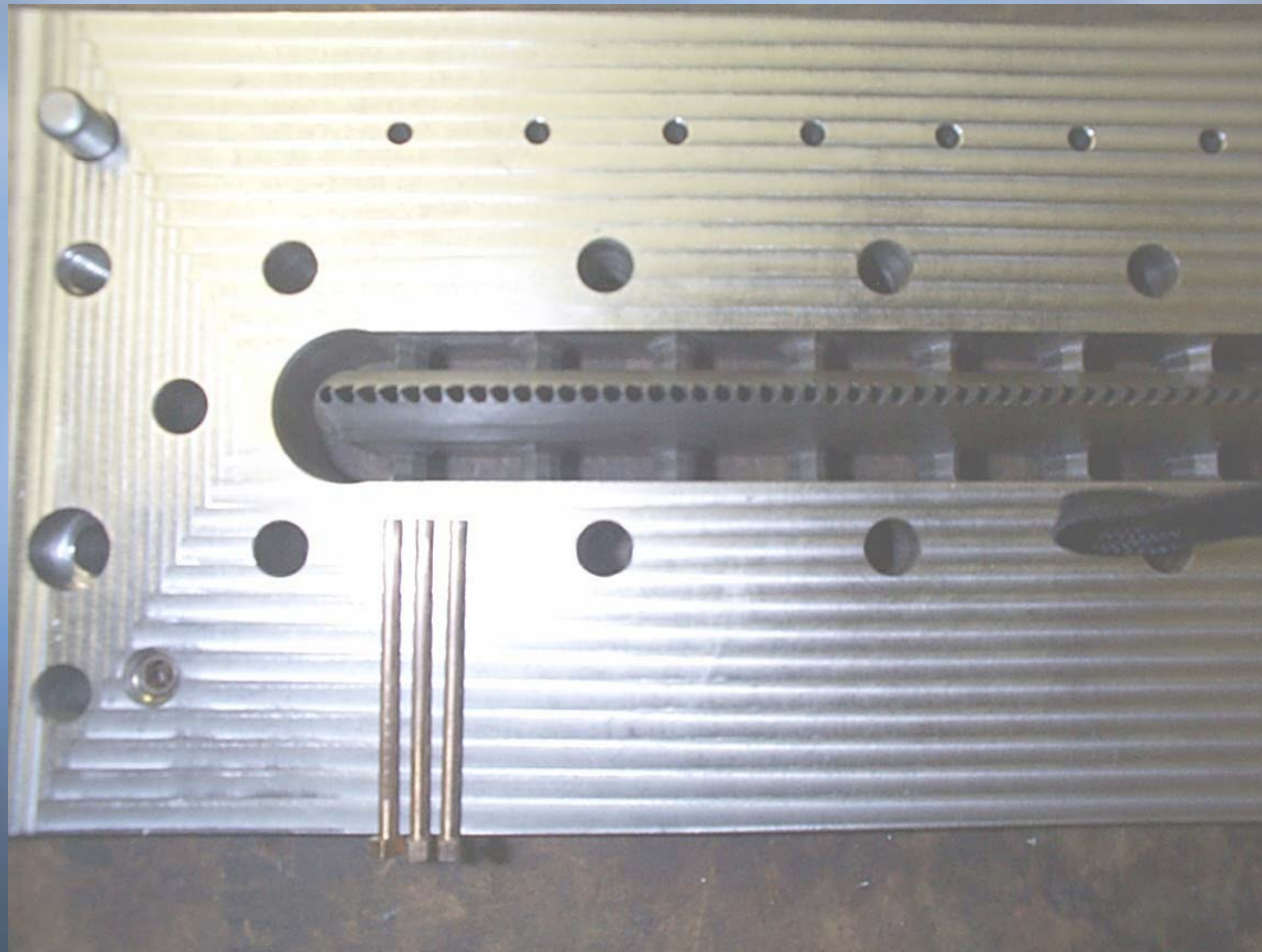
# Extrusion Die



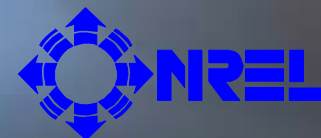
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# Extrusion Die



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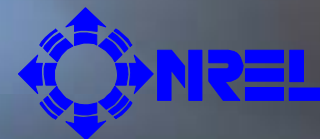
# Robotic Assembly Station



# Robotic Assembly Station



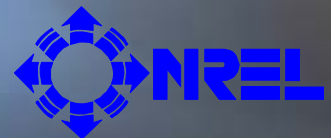
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# 40-Plate Conditioner



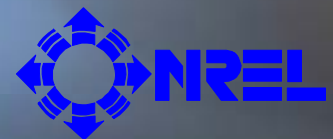
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# 6,000 cfm Conditioner



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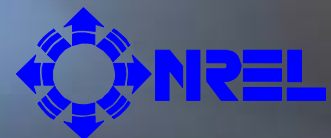


# Regenerator Development Tasks

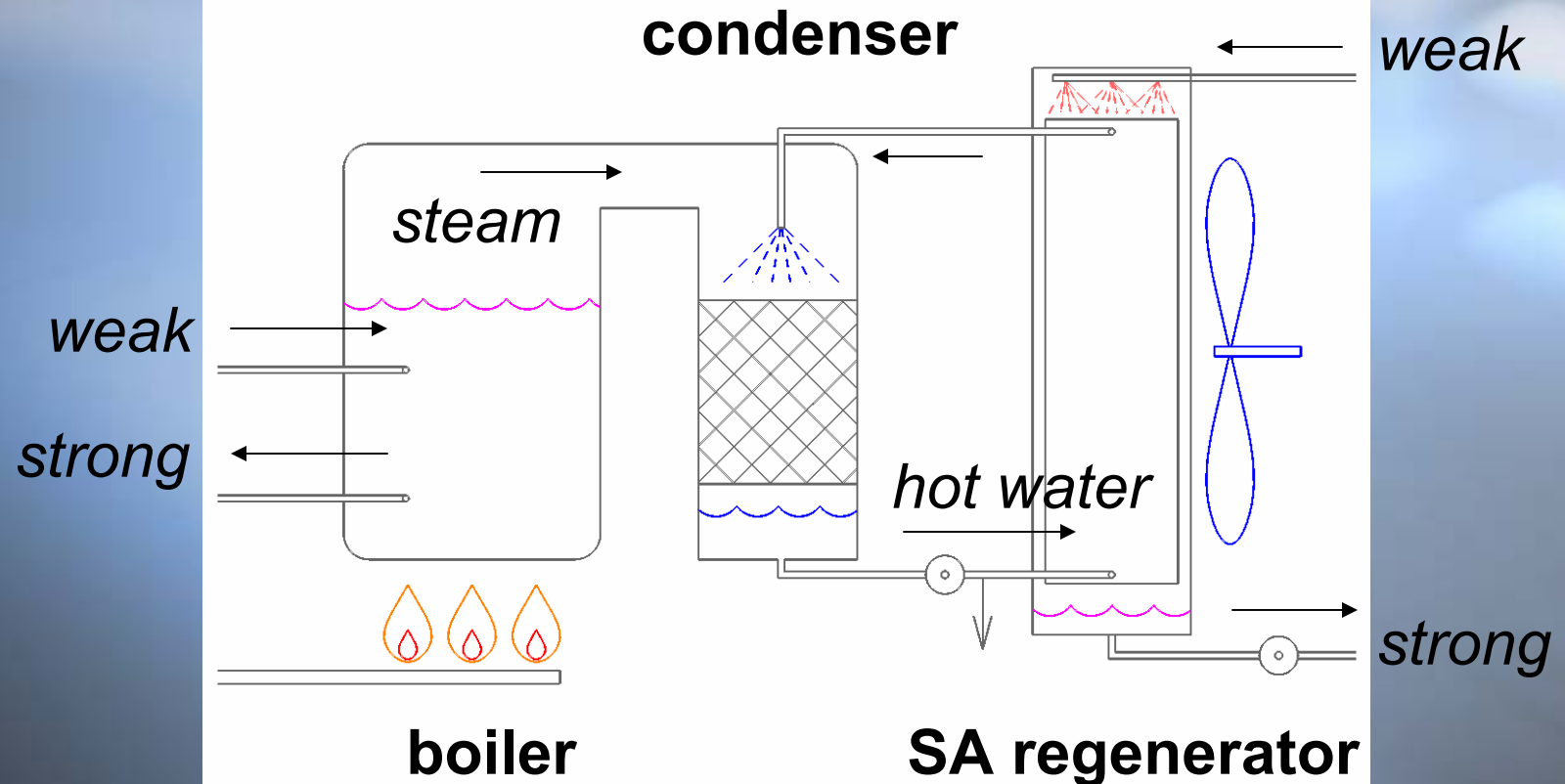
- ◆ Prove feasibility of zero-carryover scavenging-air (SA) regenerator in bench-top tests
- ◆ Prove feasibility of 1½-effect regenerator in bench-top tests
- ◆ Design, build and test SA regenerator
- ◆ Deliver model of SA regenerator to NREL
- ◆ Estimate manufacturing costs



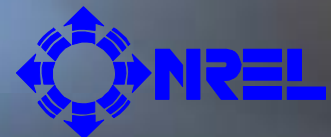
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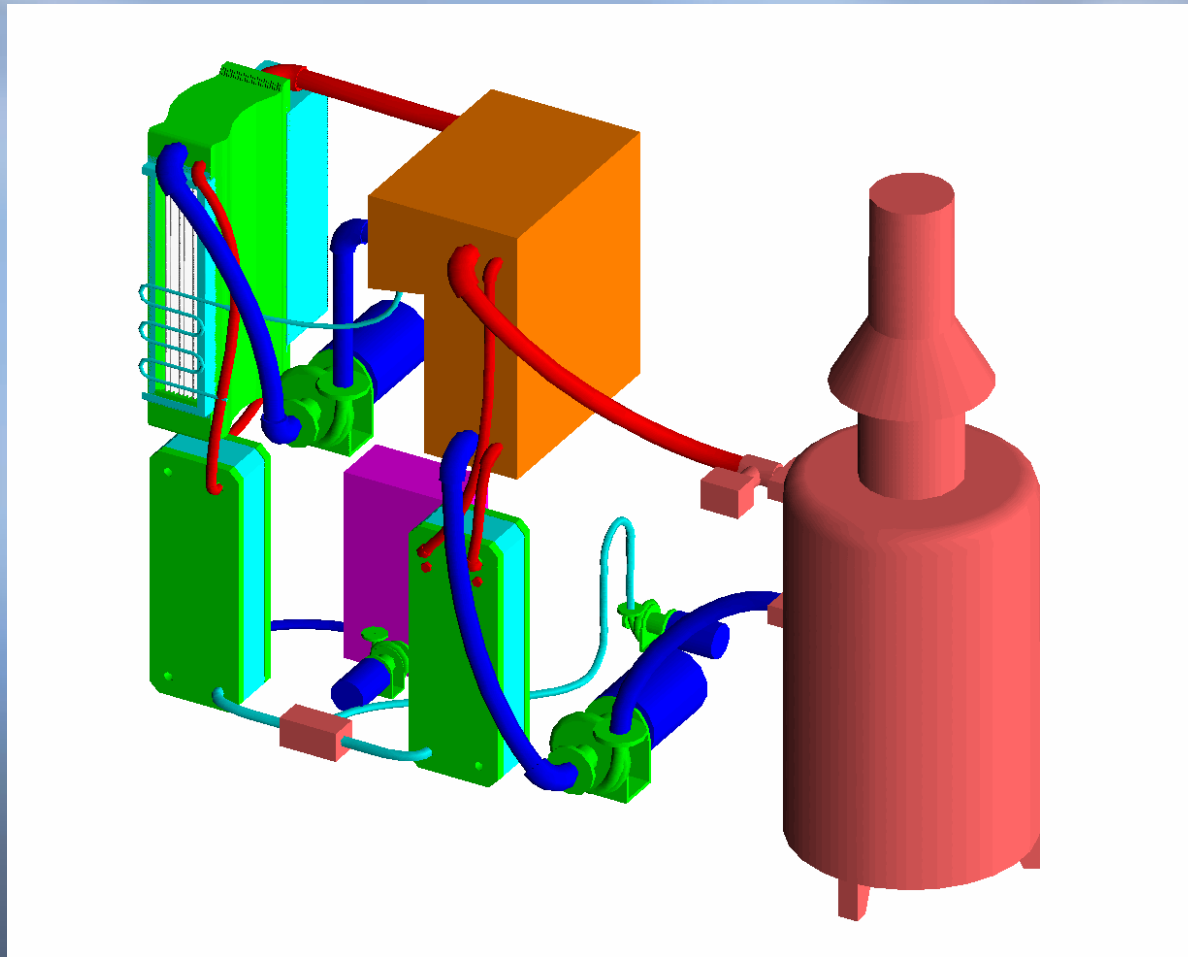
# 1½-Effect Regenerator



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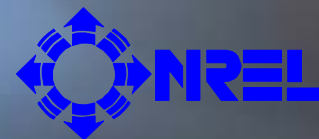
# 1½-Effect Regenerator



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# Scavenging-Air Regenerator

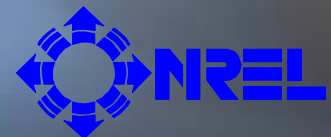


# Regenerator Development - Status

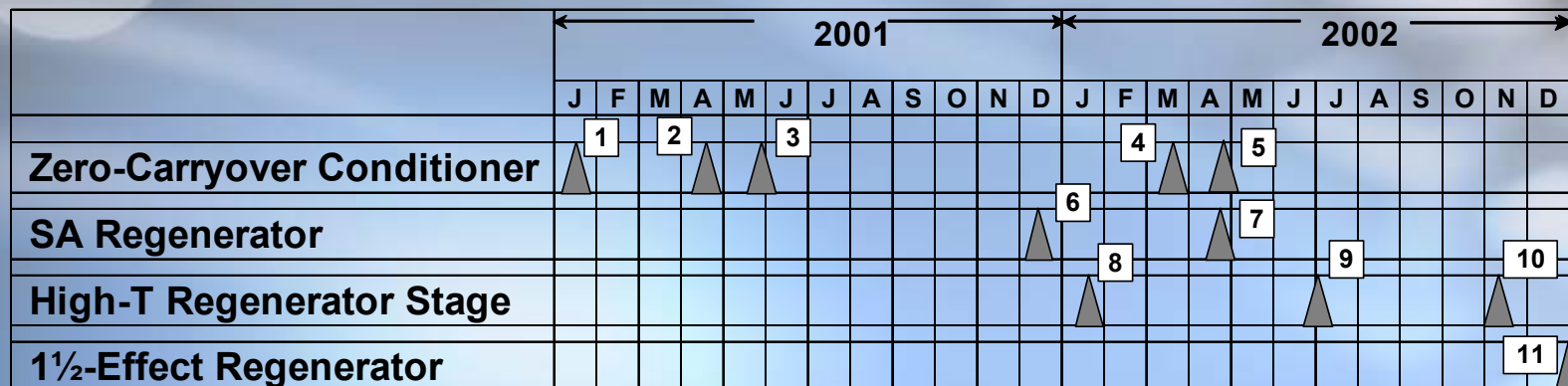
- ◆ Bench-top tests verify 0.70 to 0.75 COP for scavenging-air regenerator (about 20% improvement over state-of-the-art)
- ◆ Design heat flux achieved in bench-top test of high-temperature first stage
- ◆ 1.25 COP achievable with 320°F heat source in atmospheric-pressure 1½-effect regenerator
- ◆ 200+°F plastic plate extrusion and injection-molded parts have been fabricated.
- ◆ 4-plate model now under test
- ◆ Long-term adhesive still an outstanding issue
- ◆ Practical high-temperature stage needs to be developed



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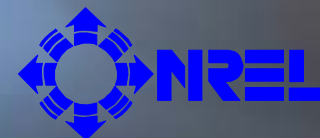
# Conditioner & Regenerator Development Milestones



- (1) Successful plate extrusion
- (2) Robotic assembly station operational
- (3) Successful molded end-pieces
- (4) Completion of NREL 40-plate model
- (5) Completion of Kathabar prototype
- (6) Performance data from bench-top test
- ✓ (7) Start of performance tests on full-plate model
- ✓ (8) Heat flux sustained in falling-film model
- ✓ (9) Conceptual design of full-scale unit
- ✓ (10) Operation of full-plate model
- ✓ (11) Start of performance tests



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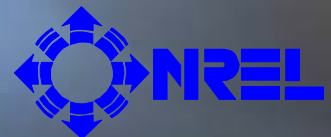


# Impact of Advanced LD Technology

- ◆ Ventilation preconditioning in humid climates
- ◆ Packaged roof-top air conditioner
- ◆ Enhanced evaporative cooling



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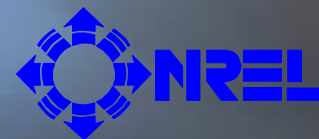
# Impact of Advanced LD Technology

## Humidity Control with High Latent Loads

- ◆ Conventional DX system with reheat
- ◆ Conventional DX system with Air-Air HX
- ◆ Enthalpy wheel preconditioning of ventilation
- ◆ Enthalpy wheel, solid-desiccant rotor & HX
- ◆ Water-cooled liquid-desiccant conditioner & CT
- ◆ Evap-cooled liquid-desiccant conditioner



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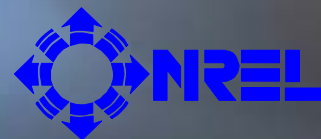


# **Impact of Advanced LD Technology Humidity Control with High Latent Loads Assumptions**

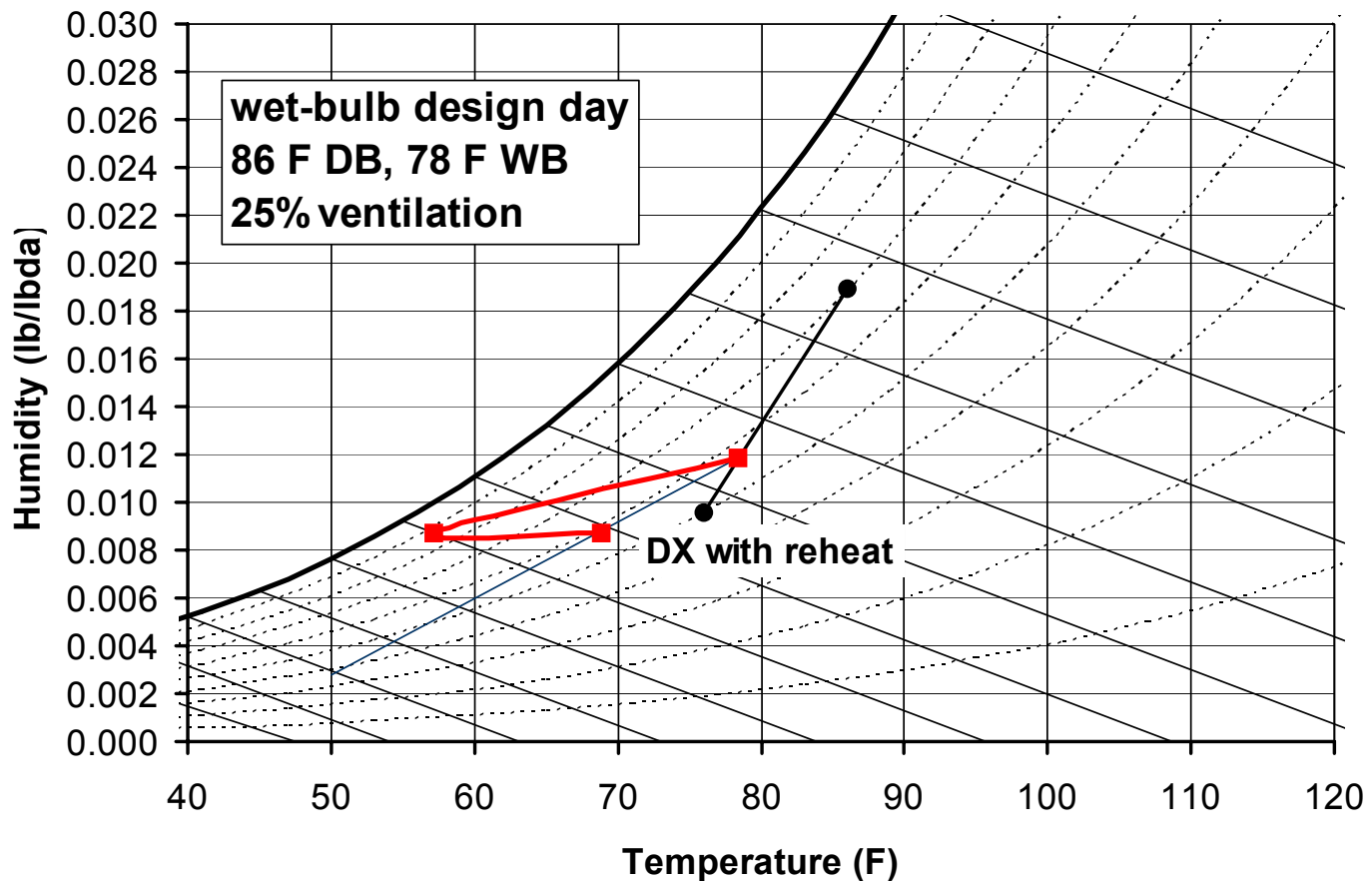
- ◆ **School in Houston, TX**
- ◆ **10,000 cfm (30% nominal) ventilation air**
- ◆ **ventilation for 13 hours per day, weekdays only**
- ◆ **April through October; summer school session**
- ◆ **Humidity loads must be met**
- ◆ **For DX, 4-row evaporator, 275 fpm face velocity**
- ◆ **80% efficient gas-fired boiler for reheat**



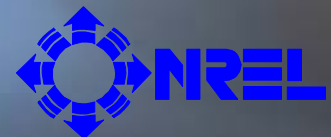
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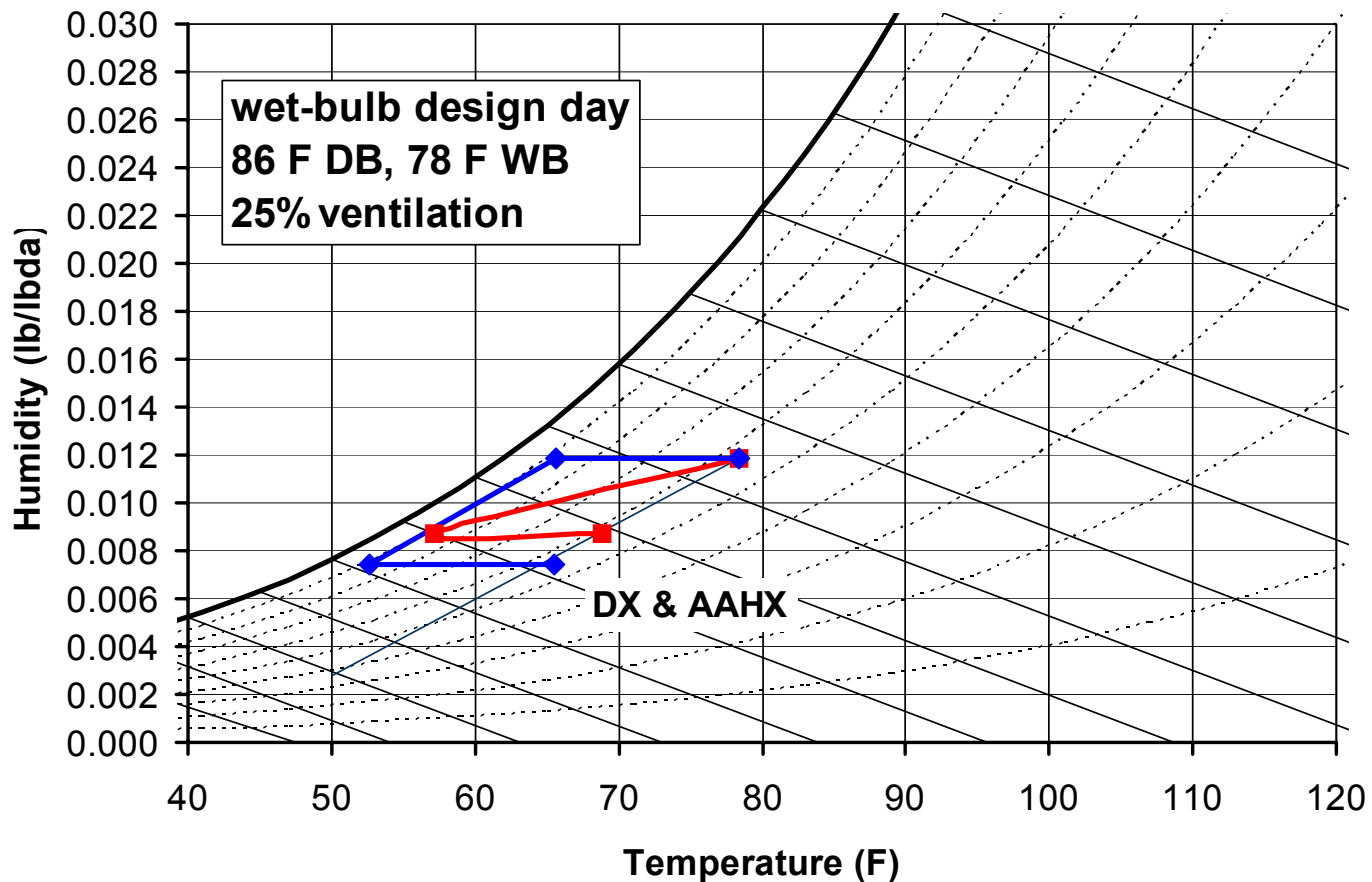
# LD Preconditioner Performance



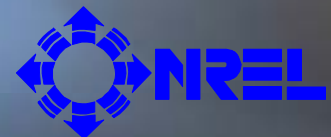
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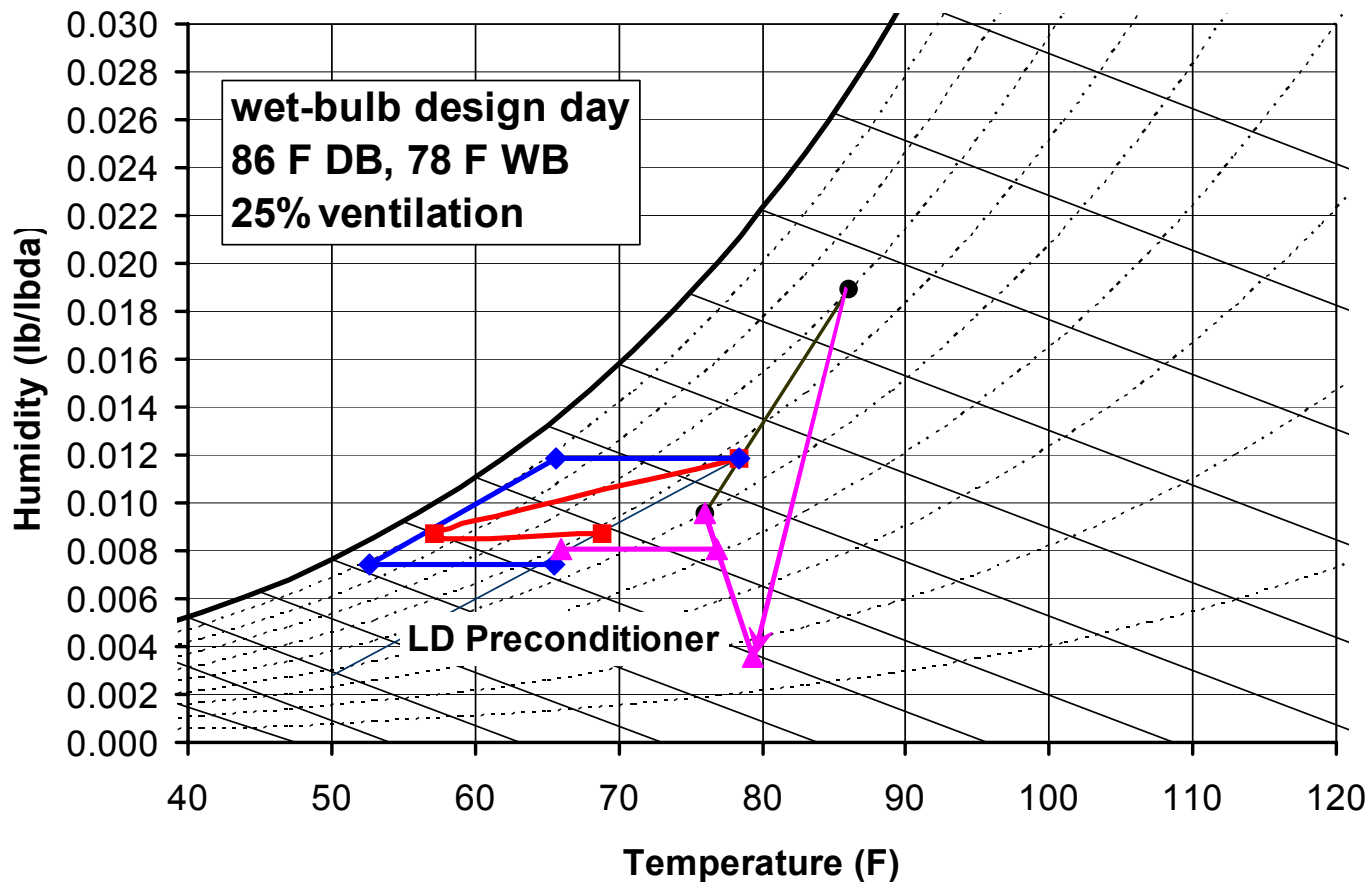
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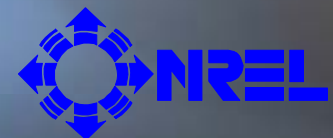
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# LD Preconditioner Performance



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# Impact of Advanced LD Technology

	no. DX units	excess sensible kBtu	compress power kWh	main fan power kWh	7-month demand kW	gas therm	cost dollars
DX with reheat	8.96	759,023	172,809	60,147	1,495	9,488	31,634
DX with 50% A-A HX	6.02	105,966	132,711	60,168	1,090	1,325	21,087
Enthalpy wheel preconditioner	7.29	373,118	120,160	48,937	1,262	4,664	23,188
EW, SD & HX preconditioner	3.22	0	63,985	21,615	566	16,088	19,673
Evap-Cooled LD; OA cooling	3.08	0	58,830	20,676	542	11,800	16,377
Evap-Cooled LD; exhaust cooling	2.87	0	53,951	19,266	503	12,000	15,803
Water-cooled LD with CT	3.74	0	82,899	25,106	663	8,285	16,891

"A-A HX" -- air-to-air heat exchanger

"EW" -- enthalpy wheel

"SD" -- solid desiccant rotor

"LD" -- liquid-desiccant conditioner

"CT" -- cooling tower

COE

\$0.06 per kWh

COG

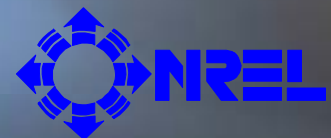
\$0.60 per therm

demand

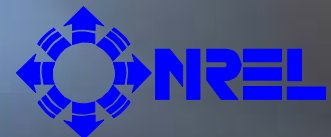
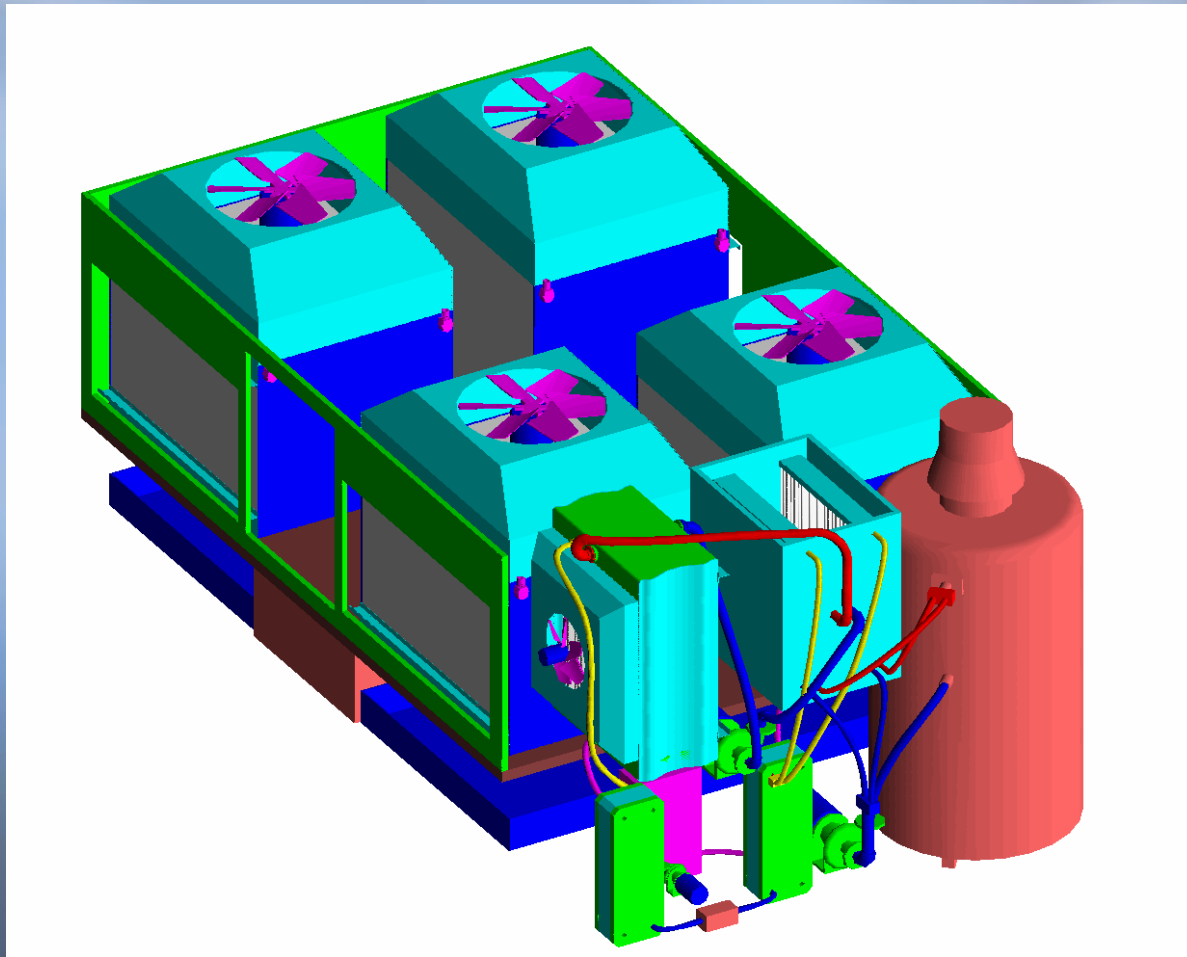
\$8.00 per kW



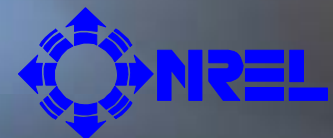
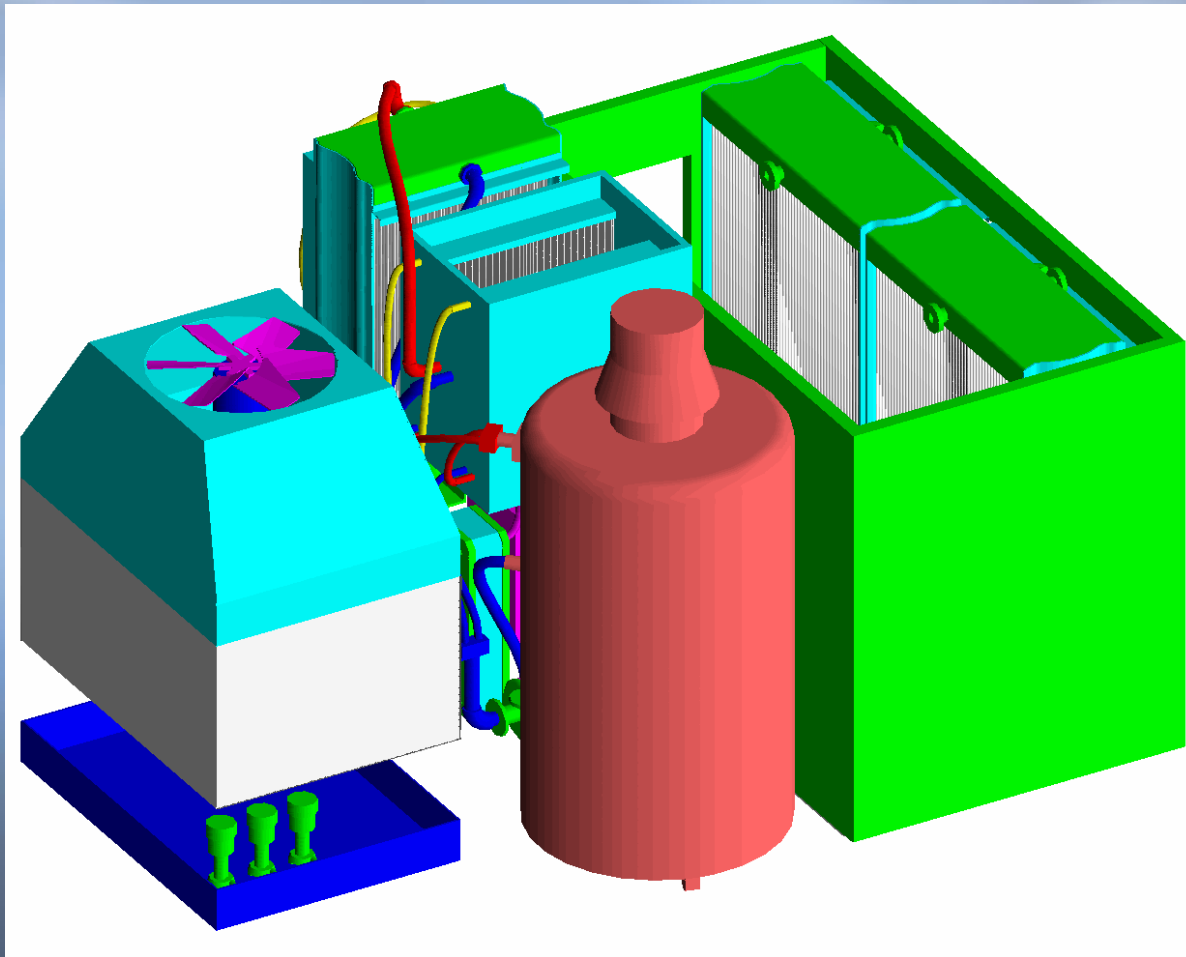
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# 10,000 cfm Evap-Cooled LD Preconditioner



# 10,000 cfm Water-Cooled LD Preconditioner



# **Manufacturing Costs**

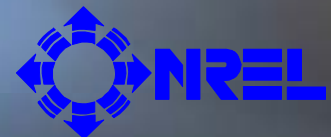
## **10,000 cfm Preconditioner**

### **500 Units per Year**

◆ <b>Water-cooled conditioner</b>	<b>\$3,250</b>
◆ <b>Scavenging air regenerator</b>	<b>\$ 765</b>
◆ <b>High-Temp regenerator stage</b>	<b>\$1,925</b>
◆ <b>Interchange heat exchanger</b>	<b>\$ 650</b>
◆ <b>Cooling tower</b>	<b>\$1,975</b>
◆ <b>Fluid heater</b>	<b>\$3,600</b>
◆ <b>Partial total</b>	<b>\$1.22 per cfm</b>



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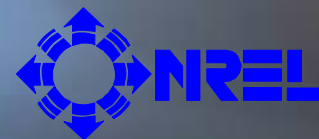


# Preconditioner Size

◆ Conventional 25-ton rooftop	67 cf/1000 cfm
◆ Solid-Desiccant preconditioner	166 cf/1000 cfm
◆ Evap-cooled LD preconditioner	68 cf/1000 cfm
◆ Water-cooled LD preconditioner	51 cf/1000 cfm
◆ Drykor preconditioner	35 cf/1000 cfm



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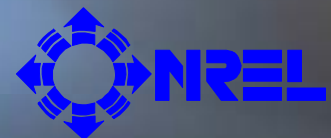


# Summary

- ◆ Low-flow liquid-desiccant conditioner ready for field demonstration
- ◆ Low-flow scavenging-air regenerator ready for laboratory testing
- ◆ Manufacturing costs for conditioner and regenerator consistent with \$5 per cfm preconditioner
- ◆ Size of liquid-desiccant systems comparable to conventional systems
- ◆ A 0.75 COP preconditioner operating on 200°F heat source could be demonstrated by end of year
- ◆ Pilot manufacturing line for conditioner and SA regenerator has been set up



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# Summary (continued)

- ◆ 1.25 COP regenerator at 320°F feasible, but engineering must be completed
- ◆ In many applications, the advanced liquid-desiccant system will be the lowest cost alternative for serving high latent loads
- ◆ Significant energy savings when regenerator is run on heat recovered from on-site fuel cell or engine-driven generator
- ◆ Commercialization path that first deploys a limited number of systems in industrial applications and then expands to institutional and commercial applications



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